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TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

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(Vol. XX.—February, 1889.)

DISCUSSION
ON
ENGLISH RAILROAD TRACK.*

By J. H. CUNNINGHAM, M. Am. Soc. C. E.
And E. E. RUSSELL TRATMAN, Jun. Am. Soc. C. E.

Mr. J. H. CUNNINGHAM.—Mr. Tratman gives details and descriptions of the track of several English railways which appear to be full and accurate, and which will afford to those who are not familiar with the bull-head rail and chair a good idea both of the several pieces of which that kind of permanent way consists, and of the manner in which they are put together. No doubt a good deal might be advanced in support of his statement that in the Colonies "a much greater extent of country might have been developed and made productive" if cheaper railways had been constructed, and perhaps, in some cases, a legitimate saving might have been effected by using the flange rail instead of the English type of track. In several important Colonies this was done, and the English track was not introduced. I believe he is practically correct in stating that the flange rail "is now the standard section of the world, being a case of the survival of the fittest, improved upon by successive generations."

* English Railroad Track, by E. E. Russell Tratman, Transactions, Vol. XVIII, No. 388, page 217.

In view of this it is not surprising that he finds it a little difficult to understand why flange rails "are not favorably considered for English railroads," and why lines "which were formerly laid with these rails have been relaid with the bull-headed rail." But I cannot agree with him in thinking that "there can be little doubt that if English railroad companies would adopt a well designed, heavy flange rail, and give it good joints and fastenings, they would have a track fully as safe and efficient as the present system, and costing no more for maintenance, but effecting a considerable saving in first cost." Mr. Tratman bases this assertion on the ground that the flange rail answers well in all other parts of the world, and that its capabilities have been proved on the principal lines in the Eastern States, where the traffic is heavy and fast. But it does not necessarily follow that because the flange rail is found to answer well in these places, it would be satisfactory in England. The fact is that a great many tracks, including flange rails, have been tried on English railways, and if we accept the testimony of those in charge of these roads we must conclude that nothing better adapted to their requirements than the bull-head rail and chair has been produced up to the present time. Mr. Tratman has collected the views of several English engineers, and his descriptions and drawings show plainly enough what are the views of others from whom he has not heard, and their unanimous opinion is that the flange rail is unsuitable for the work which has to be done on their roads. He admits that "so much testimony from so many sources must needs have some truth," but at the same time he remarks, "of course" this opinion "is largely a matter of prejudice."

Now I venture to think, that this testimony contains much more truth and much less prejudice than Mr. Tratman supposes, and that a sound conclusion as to the best form of track for English or other roads doing heavy work is not likely to be reached if we ignore it. At least before dismissing it let us clearly understand the nature of the experience from which it has been derived. Let us understand whether these opinions have been formed from experience obtained on small roads, or roads with light traffic, or from experience obtained on large roads with large quantities of heavy traffic. Let us understand whether the roads Mr. Tratman has heard from are fairly typical English railways or small and obscure branch lines. Surely it is necessary to have such information before we can form sound conclusions as to the value of this testi-

mony. But Mr. Tratman gives no hint of the existence of differences of this kind in the roads he tells us about, and in some cases the differences are very great. For instance, on page 222 we find the opinions of officials of the Isle of Wight Railway and of the Great Western Railway given without note or comment. Possibly, some of Mr. Tratman's readers may know that one of these is a small railway and the other a large one, but they may not fully realize how great the difference between them is. The fact is, that the mileage of the Great Western considerably exceeds that of any other English railway, and its capital amounts to over 36,000000 ~~$3 600~~ 000 000, while the capital of the Isle of Wight Railway is not quite $1 800 000. The Isle of Wight Railway is a profitable concern; but experience obtained from it gives no information about "English railroad track," because it is not a typical English railroad. Mr. Tratman must surely attach far too much importance to the information which he has received from this and somewhat similar lines, or he would not publish so much of it as he does. Perhaps, at the same time, he does not give due value to the testimony which he has received from lines that are large and important. He refers, at some length, to thirteen lines. Seven of these are small or have little traffic, and what may be done on them is no guide as to what ought to be done on "English railways." The remaining six are fairly typical English roads, having all kinds of traffic. Some of them serve manufacturing and mining districts and some agricultural. They all do a large general passenger business, and some of them have also a large amount of suburban traffic, in the neighborhood of London and other great cities. These six railways are the Great Western, the Great Northern, the Great Eastern, the North Eastern, the Lancashire and Yorkshire, and the Midland. The capital invested in these roads exceeds $1 662 500 000, and they earn a net annual revenue of nearly $77 500 000. Now, it appears to me, that the deliberate opinion of those in charge of a railway system of this magnitude, based upon experience which has been obtained during many years of successful working, ought not lightly to be dismissed as "largely a matter of prejudice." Further, the evidence in favor of the bull-head track, which Mr. Tratman lays before his readers, and which he is so ready to treat as of little value, is, in reality, not half of what may be produced. There are eight lines, each having a capital which exceeds $100 000 000, from which Mr. Tratman has not heard at all, or about which he tells us little, besides several smaller

though important lines, all of which use the bull-head track. In these roads, including the six just named, more than $4 000 000 000 have been invested, earning a net annual revenue of $162 500 000. The stocks of these roads are popular and sound investments. But the income on which the value of these stocks depends is only maintained by vigilant economy. Every year more work has to be done for every $1 which is earned. The public demand better accommodation, faster and more frequent trains, cheaper fares and rates, and these can only be provided without reducing the dividends by taking full advantage of improvements which reduce the expenses of working and maintenance. It is difficult to believe that those who manage this large and valuable property are seriously in error as to the type of track most suitable for their work, and in view of the opinions expressed by these gentlemen, it appears to me extremely doubtful that the alteration suggested by Mr. Tratman would be an improvement.

So far I have dealt with the magnitude of the system which has for its standard track the bull-head rail, for the magnitude of the interests involved in the roads which use that kind of track gives great weight to the favorable opinions which their officials have formed of it. Additional weight will be given to the views of these gentlemen if we reflect on their remarkable unanimity in regard to this matter. There are many differences in the details of the tracks on their roads, but yet in important features they are all much alike. As Mr. Tratman's drawings and descriptions show, various forms of fishing are in use, and various kinds of bolts and spikes for connecting the chairs to the sleepers. There are also little differences in the rail sections and in the shapes of the chairs. But in the track of each road we find an 80 to 85 pounds steel rail, in 30-foot lengths, carried in cast-iron chairs weighing 40 to 56 pounds each, and resting on transverse sleepers 10" x 5" x 9' inches, placed about 2 feet 8 inches apart, center to center. The English railway system has gradually grown up during the last fifty years. During the first half of that period a great many kinds of permanent way were tried. Experience has shown that the bull-head track is the "fittest," and, accordingly, it has survived them all. Not only is there remarkable unanimity among English engineers as to the superiority of the bull-head track, but, as we have just seen, there is even great unanimity as to the dimensions which must be given to its principal parts. An opinion about which there is so much unanimity among

persons well qualified to judge must surely contain much truth and deserve to receive more careful consideration than Mr. Tratman seems disposed to allow it.

There are some minor points in Mr. Tratman's paper about which he states the truth, but not, I think, the whole truth.

On page 224 he tells us that "it is pleasant to hear the general approval" of the flange rail "from Ireland." Three of the lines he publishes information from are Irish, and the approval of the flange rail, if "general," is also somewhat qualified. On one of these roads the bull-head rail is considered best for heavy traffic, on another it is considered best for steep grades and sharp curves, and the engineer of the third thinks the flange rail "nearly as steady as the bull-head." On Irish roads the average gross receipts are little more than £1 000 per mile per annum, whereas English railways earn four times as much, and these figures represent fairly, though perhaps roughly, the amount of traffic. As the flange rail is not found suitable for the heavy work on Irish railways, it does not seem probable that it would stand the much heavier work on English lines.

On page 247 we are told that "a 75-pound steel flange rail would probably be of ample strength for the traffic" on the Speyside Division of the Great North of Scotland Railway. Perhaps it might even suffice for the traffic of the main line. This line serves a thinly peopled district, and its traffic is only about £1 100 per mile. If its officers have not adopted the best kind of track for their road, it is a very small matter, and the experience on their line is no guide as to what should be done on English railways.

On page 242 we are told that the "original track of the West Riding and Grimsby Railway was a good example of a heavy flange rail track;" but that when the line was acquired by the Great Northern, it was relaid with their standard track, "entailing what would seem to have been an enormous and unnecessary expense." The West Riding and Grimsby was acquired by the Great Northern in 1865, and now forms a part of their main line between the West Riding of Yorkshire and London. The West Riding has a population of over three millions, chiefly engaged in manufactures of various kinds, also in mining. Any line which connects a district of this kind with London obviously must carry a great deal of traffic of all kinds, and in the absence of particulars, surely we must assume that the officials of a large and well managed

railway like the Great Northern did not change this track without having good reasons for doing so.

On page 218 we are told that the English track requires "a large amount of unnecessary metal." This assertion may be doubted, in view of the general considerations which I have already advanced. But the following facts may throw some additional light on this point. On roads having the average English gross receipts, viz., £4 250 per mile per annum, a chair weighing about 40 pounds is generally used. But the Midland, on which the receipts are £5 250 per mile, has adopted a 50-pound chair, and the Lancashire and Yorkshire, on which the receipts amount to £8 000 per mile, uses a 56-pound chair. This seems to indicate that there is no unnecessary metal in the ordinary bull-head track, but that when more than the average traffic has to be carried it is necessary to increase the weight of the average track. I may add that during the last fifteen or twenty years the weight of rails in use on English railways has risen from 75 to 80, 85 and even 90 pounds per yard, steel having been substituted for iron during the same period, while the weight of the chairs has been increased from 30 to 40, 50 and 56 pounds.

On page 224 Mr. Tratman suggests that the flange rail may have been discarded on English railways on account of the rigid wheel base so common in English locomotives and rolling stock. Rolling stock of this kind may, he thinks, require a more substantial and expensive track than is necessary for an equipment mounted on bogies. This may to some extent be the case. But the bogie controversy is too large to enter upon here; and I will merely remark that the English locomotive has been developed by the same process and under the same conditions as the English track, and it will require something more than mere assertion, unsupported by facts or figures, to show that either the one or the other is not the type best suited to the exigencies of English traffic.

In conclusion, may I say that I am not anxious to defend the bull-head rail, nor can I maintain that English, and perhaps even other engineers, are at all times wholly free from prejudice. But in reading Mr. Tratman's paper, it occurred to me that the valuable information he has gathered as to permanent way might give erroneous impressions as to English track, owing to the absence of any information as to the character of the roads he has heard from. I felt that without some knowledge of the magnitude of these roads and of the nature of their

traffic, too much importance might be attached to some of his statements, while the full significance of others might not be properly appreciated. Therefore, I have endeavored to give briefly and without detail a few facts concerning traffic and finance,* which, I think, ought to be taken into consideration along with the facts Mr. Tratman has laid before us, in order that sound conclusions may be formed as to English railroad track.

Mr. E. E. RUSSELL TRATMAN.—Having had an opportunity of looking through Mr. Cunningham's paper, I have been able to prepare the following replies to his comments and objections.

Mr. Cunningham dissents from the opinion expressed in my original paper on this subject (Transactions Am. Soc. C. E., June, 1888, page 225), that English railways could secure, with a well designed, heavy flange rail, with good joints and good fastenings, a track as safe and efficient as the present system, costing no more for maintenance and effecting a considerable saving in first cost. My opinion, however, upon this point is strengthened by the fact that one of the most important lines in England, the North Eastern Railway, which has been using 90-pound bull-headed rails in 40-pound chairs, is now experimenting with 90-pound flange rails laid on steel cross-ties. The cost for one mile of single track, inclusive of laying complete, but exclusive of ballasting, is about $6 336 for the bull-head rails in cast-iron chairs on wooden ties, and $7 046 for the flange rails on steel ties. This I consider to be a step towards the ideal track for railways with heavy traffic, and in this country a step is being made in the same direction, as the New York Central and Hudson River Railroad is about to experiment with a section of track laid with its 80-pound flange rails on steel ties. In referring to the ideal track I do not mean to say that I consider that either the North Eastern or the New York Central track will be the track of the future, as the ideal track of the future will probably be gradually developed from different experiments with different types of steel ties under different conditions, but I do consider that the track of the future will be a metal track.

In answer to the objection that of thirteen railways whose tracks I have described in my paper, seven are lines of minor importance, I have only to say that that paper was intended to describe English tracks of different kinds, and not only those of the trunk lines, while the main object of the paper was to describe and not criticise. With six of the most important lines in England, one line which has been converted into a part of a trunk line system (the West Riding and Grimsby), three of the principal Irish lines, and three lines of second or third rate im-

* These figures are for the year 1887, and have been taken from Whitaker's Almanac, 1889. $5 have been taken as equivalent to £1 sterling.

portance, including a Scotch branch line, I think my paper has fairly represented the varieties of English practice. I do not, however, as suggested, attach too much importance to the use of flange rails on these second or third rate lines, but I have borne in mind the fact that in this country an enormous traffic is carried over comparatively light flange rails in freight cars of 40 000 to 60 000 pounds capacity (weight of cars from 15 000 to 30 000 pounds), passenger cars weighing 45 000 to 50 000 pounds, and sleeping cars weighing from 70 000 pounds to 86 000 pounds, hauled by ponderous locomotives; and I fail to see why a really good track of this type should not be, under proper conditions, satisfactory for railways in England or any other country. The following table will give some idea of the capabilities of the average American track (the weights of rails are partly taken from Poor's "Manual of Railroads"):

New York, Lake Erie and Western.
Rails.....................................63, 67 and 74 pounds.
"Eight-wheel;" 115 000 pounds total weight; 78 000 pounds on the four drivers.

New York, New Haven and Hartford.
Rails...up to 74 pounds.
"Eight-wheel;" 112 000 pounds total weight; 70 000 pounds on the four drivers.

Pennsylvania.
Rails...up to 85 pounds.
"Eight-wheel;" 96 330 pounds total weight; 32 530 and 32 650 on drivers.

Union Pacific (Wooten fire-box).
Rails........................56 pounds (some probably heavier).
"Eight-wheel;" 118 000 pounds total weight; 76 500 pounds on the four drivers.

Lake Shore and Michigan Southern.
Rails.......................................60 and 65 pounds.
"Eight-wheel;" 37 500 and 35 700 pounds on drivers.

Chicago and North Western.
Rails...56 to 72 pounds.
"Eight-wheel;" 90 000 pounds total; 57 800 pounds on the four drivers.

Delaware, Lackawanna and Western.
Rails.......................................60 and 68½ pounds.
"Mogul;" 98 000 pounds total; 87 000 pounds on the six drivers.

Michigan Central.
Rails.....................................56, 60 and 80 pounds.
"Mogul;" 102 000 pounds total; 29 000, 30 000 and 28 600 on drivers.
"Ten-wheel;" 118 000 pounds total; 94 000 pounds on the six drivers.

Colorado Midland.

Rails..65 pounds.

"Ten-wheel;" 121 000 pounds total; 99 000 on the six drivers.

Canadian Pacific.

Rails...................................56, 60 and 72 pounds.

"Eight-wheel;" 95 800 pounds total; 64 800 pounds on the four drivers.

"Consolidation;" 104 000 pounds total; 90 900 pounds on the eight drivers.

With regard to the Isle of Wight Railway, the fact that a 70-pound flange rail has been replaced by a 78-pound double-headed rail in 35½-pound chairs, should, I think, be left out of consideration, as it does not appear to prove anything on either side, for there must certainly have been special reasons for this action. The traffic is light, about fourteen trains each way per day, mostly passenger trains, and these trains are not heavily loaded; if a 70-pound flange-rail bolted to cross-ties will not carry this traffic in England, when a 56 to 70-pound rail spiked to the ties carries and has carried an immense amount of heavy freight and passenger traffic in America, there must be some reason beyond the type of track. It may have been that the flange rails were worn out, and that in relaying it was considered advisable to adopt the standard English form of track; but if so, that would tend, I think, to prove that adaptability and the exercise of true economy are not features of English practice. For important lines with heavy traffic I believe the heaviest track is the best and most economical, but I do not favor the indiscriminate adoption of heavy track for roads of all classes. For lines of this class over here, a 56 to 65-pound rail would probably be considered sufficient. As to the use of heavy flange rails, the adoption of the 110-pound "Goliath" rail (designed by Mr. C. P. Sandberg) in Belgium, and the recent orders that have been given for large quantities of these rails, point to the general feeling in favor of this section. Flange rails of this weight have recently been rolled by the Barrow Steel Company of England for the government railways of Victoria, Australia. Before quitting this subject, I beg leave to quote as follows from the foot-note on page 222 (of my original paper), which was in answer to the remark by Mr. Forrest (Secretary Inst. C. E.), that continental engineers prefer the double-headed rail in chairs, and are only prevented from using it by reason of the extra expense: "I cannot think that Mr. Forrest is correct in this remark, as the flange rail is almost universally adopted on the continent, even on State railway systems, where a little extra expense would not prevent the adoption of a specially good form of rail. Many of the double-headed sections used on the continent have been of bad and clumsy design, some resembling an hour-glass in section. Heavy flange rails are the most modern type adopted and approved, which is a step in the right direction." (See also Mr. C. P. Sandberg's

paper on "The Use of Heavier Rails for Safety and Economy in Railway Traffic," published in October, 1888.)

I am very far from intending to say that the English track is not good; it is good, it is a splendid track, but it is enormously expensive in first cost, and few countries but England could afford to put so much money into the cost of construction. They have a good track, and it has been paid for; therefore it would probably be false economy to take it up and replace it with a track of a different type, and I do not wish to be understood as recommending it, although Mr. Cunningham seems to suppose so. Still less should they want to take any such radical steps while their rail manufacturers guarantee to replace broken rails free of cost for terms of five to twelve years. For new lines, however, of whatever class, I believe a flange rail track of equal efficiency with, and greater economy than, the present system, can be designed. It is the American type of track (as it should be), and not the American track, as it too often is, which I am advocating, as will be understood from what I have said.

As to the Irish lines, I think I have fairly stated the case in giving verbatim the statements of the engineers, and as to the Scotch line, it may be a "very little matter," as Mr. Cunningham says, if too heavy a track is laid on a line serving a thinly peopled district; but that is where the want of adaptability and economy is shown, and what is done in Scotland in this way may very likely be done in England. I do not suppose that the officials of the Great Northern Railway changed the track of the West Riding and Grimsby line without having good reasons for doing so, according to their views, but I question the necessity for so doing, looking at the matter from my point of view. For it must always be remembered that there are two sides to every question, and it was with the object of showing clearly the other side of the question that I quoted so fully in my paper the statements of the English engineers.

The chairs I consider to be the "unnecessary metal in the track," judging from the experience of roads in America and other countries. For lines with heavy traffic, an increased bearing area can be obtained by the use of metal bed-plates or sole-plates, such as are used under flange-rails on the European continent, thus avoiding the metal in the upper part of the chair, which is necessary with the English track in order to hold the rail up. A good flange rail track cannot be maintained with spike fastenings; but by the use of coarse threaded wood screws with washers and square heads, or by bolts and washers, screwed up from above, a good track may be maintained and easily kept in good condition. Such fastenings would greatly facilitate the keeping up of the joints. The Pennsylvania Railroad is about to try screw fastenings in combination with iron bed-plates. At present the American rail with its spike fastenings has a vertical motion very far back from the joint, while the English rail rigidly secured in a chair which

is firmly attached to the tie has no vertical play back of the joint chairs; for that reason four bolt joints are used, and though deep splice bars have been adopted on some roads, straight bars are still extensively used. The wood keys which secure the rail in the chair, being generally of creosoted and compressed wood, do not give much trouble in England; but in India and other hot countries where the English track has been introduced, considerable trouble has been experienced. An inherent conservatism has no doubt something to do with the continued use of the chair. The Leicester and Swannington Railway, built by Stephenson, and open in July, 1832, had the "fish-bellied" rails carried in chairs of practically the same form as those now in use; they had a base of 9¼ x 4½ inches, and the rails were secured by wooden keys. This is but one example of early English railways using chairs. Then it has been suggested to me that switches can be made safer and more efficient with double-headed or bull-headed rails in chairs than with flange rails, but I think perfectly satisfactory switches can be made with the flange rail.

Mr. Cunningham suggests that I do not sufficiently appreciate the question of traffic, or the almost unanimous opinions of English engineers, based upon experience; but on this point I do not agree with him. To return the compliment, however, I do not think Mr. Cunningham sufficiently appreciates the question of rigid versus flexible wheel-base. The English locomotive has, as he says, been developed by the same process and under the same conditions as the English track, and it requires an exceptionally heavy track, which the English track undoubtedly is. A four-wheeled English passenger car has a rigid wheel-base of about 15 feet, while a six-wheeled car has probably a wheel-base of 20 to 25 feet. It may be said that the English systems of track and rolling stock go together, while the American systems also go together. But that the American system of flexible wheel-base is well adapted to English track is proved by the extent to which it has been adopted in that country for locomotives and rolling stock, while the adaptability of an English engine to American track will be shown to some extent by the compound engine imported for the Pennsylvania Railroad. That engine, however, has a radial arrangement for its leading axle, but a radial axle in such a position is generally thought to be inferior to the truck or "bogie."

I am sure that the American track is underestimated in England; for the Chief Engineer of the Midland Railway (who is quoted in my paper as saying that with the American track, "under the great velocities and heavy weights on the driving wheels of our engines, I think the road would be broken up in a few hours; in fact, in some cases it would not stand the passage of a single train") has written to me asking for information as to the weight of the track of the main lines in this country, as he was not aware that any but light track, something similar to what

is used in England for construction purposes, had been laid here; and I have recently sent him particulars of the New York Central 80-pound rail, the Pennsylvania 85-pound rail, and the Philadelphia and Reading 90-pound rail; also of a proposed rail of the "Sayre" pattern to weigh 110 pounds per yard. I have also sent particulars of the weights of engines on the light tracks of the Western roads and the heavy tracks of the best Eastern roads. In acknowledging the receipt of these particulars, this gentleman states that he thinks that if I compare the traffic per mile on English and American lines it will be found that on the latter it is "very small, indeed," even on the busiest parts, as compared with English traffic. He also says that he has had experience with flange rails, but has always been obliged to limit the speed in order to prevent derailments. As to the traffic, I would call attention to the high speed of the express trains on the trunk lines, and the great weight of freight trains all over the country. If a comparatively light track (on the average) will carry such traffic here, I cannot see why a first-class track of the same type, under proper conditions, should not suffice to carry the traffic on English roads; and carry it safely and economically.

In conclusion, I beg to say that I consider Mr. Cunningham's paper a valuable addendum to my original paper, on account of the information which it contains; but it has not shown my expressed opinions to have been based on weak or unstudied foundations, nor has it shaken my conviction as to the superiority of the American type of track for railways in every country.

AMERICAN SOCIETY OF CIVIL ENGINEERS.
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EXPERIMENTS ON THE STABILITY OF BENCH MARKS.

By GEORGE W. COOLEY, M. Am. Soc. C. E.

READ OCTOBER 3D, 1888.

WITH DISCUSSION.

The following table of experiments is submitted to show the relative change from year to year in the elevation of bench marks as generally made on trees.

The location was in mixed timber, partly exposed to the sun, on the shore of Lake Minnetonka, near Minneapolis, Minn.

Surface soil—vegetable loam, 12 inches. Subsoil—stiff yellow clay. Elevation above lake, 40 feet. Penetration of frost, 3 feet.

The standard bench was made as follows: A 3-inch hole was bored in the clay 7 feet deep; inside of this was placed a galvanized iron tube, in the centre of which was an inch iron gas pipe 8 feet long, driven into the stiff clay at the bottom of the hole 18 inches, the whole covered with a water-tight cap and 6 inches of earth. Elevations were taken yearly about October 1st, under favorable conditions. No upward growth was discovered, but a change from one to three-hundredths of a foot, from year to year, probably caused by action of frost during the winter.

The greatest change in any one year was .03, and the greatest net change in five years .02.

TABLE No. 1.

Showing Relative Change from Year to Year in the Elevation of Bench Marks as Generally Made on Trees.

KIND OF TREE AND DIAMETER, INCHES.	Elev. 1882.	Elev. 1883.	Rise + or Fall −	Elev. 1884.	Rise + or Fall −	Elev. 1885.	Rise + or Fall −	Elev. 1887.	Rise + or Fall −	Elev. 1888	Rise + or Fall −
....	....	....	1 year..	....	1 year..	....	1 year..	....	2 years.	....	1 year..
No. 1, Linden, 3........................	100.6916	100.7016	+.01	100.687	−.0146	100.690	+.003	100.669	−.021	Rotted.	....
No. 3, Ironwood, 12......	100.9596	100.9756	+.016	Dead.	....	....	....	....	....	....	....
No. 4, Hickory, 3.....	100.066	100.091	+.025	100.062	−.019	100.076	+.014	100.067	−.009	100.064	−.003
No. 5, Linden, 12..............	100.896	100.929	+.033	100.913	−.016	100.904	−.009	100.896	−.008	100.903	+.007
No. 6, Maple, 4.....	99.9716	100.000	+.0284	99.983	−.017	99.980	−.003	99.971	−.009	99.985	+.014
No. 7, Elm, 4...........................	....	99.958	....	99.973	+.015	99.959	−.014	99.947	−.012	Rotted.	....
No. 8, Linden, 5.................	....	99.780	....	99.813	+.033	99.800	−.013	99.802	+.002	99.777	−.025
No. 9, Elm, 20......................	....	98.981	....	99.015	+.034	98.993	−.022	98.996	+.003	98.973	−.023
....	....	....	....	....	....	....	....	....	3 years.	....	....
No. 10, Linden, 18	....	97.002	....	97.023	+.021	....	....	97.007	−.016	96.996	−.011
....	....	....	....	....	....	....	....	....	2 years.	....	....
No. 11, Linden, 12........................	....	96.470	....	96.489	+.019	96.479	−.010	96.467	−.012	96.458	−.009
No. 12, Maple, 20	....	97.457	....	97.471	+.014	97.459	−.012	97.457	−.002	97.437	−.020
No. 13, Ironwood, 10......................	....	97.318	....	97.343	+.025	97.322	−.021	97.311	−.011	97.300	−.011
No. 14, Black Oak, 12.....	....	97.164	....	97.183	+.019	97.172	−.011	97.164	−.008	97.146	−.018
No. 15, Maple, 10	....	95.892	....	95.923	+.031	95.921	−.002	95.883	−.038	95.873	−.010
No. 16, Maple, 20.........................	....	....	....	....	....	96.071	....	96.067	−.004	96.043	−.024

TABLE No. 2.

TOTAL VARIATIONS.

	Diameter, Inches.	Years.	
Linden	3	5	—.0226
Ironwood	12	1	+.016
Hickory	3	6	—.002
Linden	12	6	+.007
Maple	4	6	+.0134
Elm	4	4	—.011
Linden	5	5	—.003
Elm	20	5	—.008
Linden	18	5	—.006
Linden	12	5	—.012
Maple	20	5	—.020
Ironwood	10	5	—.018
Black Oak	12	5	—.018
Maple	10	5	—.019
Maple	20	3	—.028

DISCUSSION.

J. JAMES R. CROES, M. Am. Soc. C. E.—I think that Mr. Odell has some data in regard to differences of elevation in the same bench mark in the vicinity of New York.

F. S. ODELL, M. Am. Soc. C. E.—I have noted some changes in bench marks, but am not able to give the exact differences; I think it was due to some settlement of the foundations of the bench mark. They were taken on the basin covers of the receiving basin in 129th Street, in the vicinity of Second and Third Avenues. There seemed to be about ¾ of an inch difference, as near as I can remember, in relation to other prominent objects in the same vicinity.

Mr. CROES.—Was there not an instance where a point which was supposed to be pretty permanent was found to vary every few days?

Mr. ODELL.—Well, not every few days, but every few months. I think you probably refer to the bench marks on the stairway foundations, but we hardly considered those to have been of such a construction that they would not vary somewhat; we found they did vary, but we thought it was due to the nature of the foundation.

By reference to the notes I find that the basin cover at 129th Street and Second Avenue settled 0.130 of 1 foot in eighteen months, while that at 129th Street and Third Avenue had become 0.060 of 1 foot higher during the same period, and the stairway foundation had settled 0.240 of 1 foot.

Mr. A. Fteley, M. Am. Soc. C. E., stated that in connection with water gaugings which required accurate levels to be taken of the surface of water running in a long flume, and the surrounding grounds being very swampy and unreliable for the establishment of ordinary benches, he used to advantage some long iron rods driven through many feet of swampy mud into the solid bottom. The top of the rod furnished permanent and very accurate benches.

H. W. Brinckerhoff, M. Am. Soc. C. E.—Some eighteen years ago or more Mr. John F. Ward, M. Am. Soc. C. E., then chief engineer of the Jersey City Water Works, and whose assistant I then was, put a couple of standard benches in the Jersey City parks, each of which consisted of a 2½-inch iron rod perhaps 8 feet in length; the upper end stood just out of the ground and was slightly convex, while the lower end had cast around it a disk of cast-iron about 2 feet in diameter. Of course they had to have a hole dug to set them; but after they had been set they could be depended on for all time, I presume, as they were anchored below the reach of frost or other probable disturbance. They gave very satisfactory results as long as I had occasion to use them, and I understand they are still unmoved and in good condition.

P. F. Brendlinger, M. Am. Soc. C. E.—I was very much interested in the paper this evening; the fluctuations from year to year are certainly very interesting and curious. It strikes me, however, that Mr. Cooley should have had more than one permanent gas pipe bench to compare with, or better still, have this one gas pipe bench and one of some other material somewhat deeper in the ground, then compared these benches with those on trees. This fluctuation reminds me very much of a case we had in Pittsburgh in 1875. There was a high water mark established on a brewery. This was a flood mark; the highest flood ever recorded in Pittsburgh, that of 1832. In 1875 I had occasion to build a bridge in that vicinity, the Point Bridge. We had to raise the street at the brewery. Some engineers took elevations on that high water mark; it was about 34 feet above low water level; one year, 1877, they found it was 35½ feet; it had risen a foot and a half in two years. They could never understand how that was until I explained that I had raised the building 18 inches and the high water mark went up with it and was never lowered.

Mr. Croes.—Had they been working from that bench in the meantime?

Mr. Brendlinger.—They tested it; they said it had risen rapidly in the two years.

George W. Cooley, M. Am. Soc. C. E.—I think there can be no question as to the stability of my standard bench. Two reference benches were established at the same time—one of the same description and size, and another of gas pipe driven into the bottom of the lake below the reach of ice or other disturbing cause. The latter was used to regulate a water gauge and the gauge frequently tested by the standard bench. Tests made during the first three years of the experiments showed no change in the standard; and it seems impossible that there should be any, as the pipe was not in contact with the earth at any point except 7 feet below the surface, and was well protected. Another circumstance in connection with these experiments not mentioned in my paper was the fact that nails driven into some of the trees about four feet above ground maintained for five years the same relative position with regard to the nails on the benches. Only three of these were tested, the others being covered with a growth of bark.

AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852.

TRANSACTIONS.

405.

(Vol. XX.—February, 1889.)

DESCRIPTION OF GUARD GATES AT THE POINT STREET BRIDGE AT PROVIDENCE, R. I.

By WILLIAM D. BULLOCK, M. Am. Soc. C. E.

The Point Street Bridge spans the Providence River, and is located about one-half mile below the head of navigation.

It consists of three spans. Each of the two fixed spans has a clear span of about 143 feet, and the draw span, located between the latter, is 250 feet long, over all, with two clear openings for the passage of vessels, of 100 feet each. The fixed spans are of the Mosely Arch pattern, and were built by the Mosely Iron Company of Boston about 1869-70. The draw span was built by Charles Macdonald, M. Am. Soc. C. E., to replace the original one built by the Mosely Iron Company, which proved unsatisfactory. It is supported on a Seller's table, and is operated by steam power, the engine being located at the draw center, as shown on the general plan, Plate III.

This bridge is a through bridge, with one driveway 24½ feet wide between wheel guards, and two sidewalks each about 6 feet wide, the total width out to out being 40 feet.

The bridge was opened to travel October 22d, 1872, and no guard gates were placed upon it until some time in the fall of 1874, when one gate was placed at each end of the bridge, closing only the right hand half of the driveway. These gates, which were erected at a cost of $1 000, consisted of a single bar, similar to those in use at railroad crossings, and were operated from the draw center. They were in use until 1875, when they were removed, having proved unsatisfactory as safeguards, and giving much trouble in operation.

From that time until the erection of the present gates, the bridge has been without guard gates or protection of any kind when the draw was open.

The number of teams passing over this bridge daily from 6.30 A.M. to 6.30 P.M. varies from about 1 200 to 1 500, and the number of pedestrians passing within the same hours is about 3 000.

The average number of daily openings of the draw for the years 1885–88 was 38; and the greatest number of openings for the twenty-four hours of any one day during the same years was 79. The average time that the bridge was closed to travel, for each opening of the draw for the above-named years, was 4.52, 4.58, 4.29 and 3.72 minutes respectively.

No trotting over the bridge is allowed, and all teams are required to keep to the right.

March 20th, 1883, a resolution of the City Council was approved directing the Committee on Bridges to erect guard gates at the Point Street Bridge.

The problems presented for solution in designing gates for this location were difficult ones. The gates must be safe; must close the approaches to the draw to both pedestrians and teams; must be operated and controlled at the draw center; must not interfere with the operation of the draw nor call for additional help; must cause but little, if any, delay to travel over the bridge, or to navigation through the draw openings.

Under these conditions the writer was called upon to make designs for the gates. Careful inquiry failed to show any precedent in the construction of gates under such conditions.

An exhaustive study of the subject was made, and sketch plans prepared, in which the application of water, compressed air, and electricity as motors was considered. These, although more easily operated and

controlled from the draw center than steam, were attended with special difficulties, and would probably be more expensive in maintenance. Steam power was not at first regarded with favor, owing to the apparent difficulty in designing suitable connections between the draw and shore spans. Finally the solution of the problem seemed to depend upon the discovery of some device by means of which the power, located at the draw center, could be transmitted to the gates on the fixed spans. After much study the tongue and grooved slide attachment, as shown on the accompanying plans, was devised, by means of which a simple, positive and automatic connection between the draw and fixed span was secured, which has proved entirely satisfactory.

With suitable connections thus assured, the steam power used in operating the draw became the most available power for operating the gates.

The following description, with Plates III, IV, V, VI, will explain the construction of the gates and machinery, and the manner of operating them.

By reference to the general plan, it will be seen that the gates are located on the fixed spans about 16 feet from the ends of the draw, thus leaving a space on the fixed span where pedestrians may wait when stopped by the gates; and also permitting the gates to be closed as soon as possible after the teams leave the draw.

The gates swing on vertical posts, and the frames are constructed of channel iron, with diagonal tie rods with turn-buckle adjustments.

To the frames are bolted $1 \times 2\frac{3}{4}$ inches yellow pine pickets, of such length as to give a height for the gates of about 5 feet 3 inches above the floor. The posts are of solid wrought iron $2\frac{1}{4}$ inches square for the driveway gates, $1\frac{3}{4}$ inches square for the sidewalk gates, and $1\frac{5}{8}$ inches square for the safety gates. These posts extend through and beneath the flooring, and to this extension of each driveway gate post is attached a 24-inch spur gear, which meshes into a like gear on the sidewalk gate post. To the driveway gate post just below the 24-inch gear is also attached a 36-inch grooved pulley, around which passes the wire rope by which the power is applied.

The driveway is closed by two gates swinging from the truss towards the center, and both latching to the same wooden post in the center of the driveway. Each sidewalk is closed by two gates, the larger one swinging from the truss towards the outside of the sidewalk. Opposite

to the latter, upon an extension of the sidewalk, is placed a small safety gate, so arranged that it is free to swing until the end of the sidewalk gate swings nearly opposite to it, and the space (3 or 4 inches) between the ends of the two, is too small to permit a person to get caught between them, when a latch beneath the flooring is thrown by an arm on the sidewalk gate gear, and the safety gate is securely fastened.

The driveway and sidewalk gates swing away from the draw when closing, and towards the draw and away from the waiting public when opening.

At the upper end of each driveway gate post is placed an alarm bell, which is rung at short intervals by the movement of the gate when swinging in either direction. The weight of each driveway and sidewalk gate is supported by a steel collar shrunk on the post, and turning on a bronze ring, held firmly in place by a cast-iron shoe bolted to the flooring. All of the gates are painted white, which contrasts with the olive color of the bridge, and thus makes them more conspicuous as barricades in case of runaways.

Operating Machinery.

The gates are closed by steam power and are opened by counter weights.

Supported upon the turn-table of the draw beneath the flooring is a horizontal shaft carrying two grooved drums, and connected with the engine by gearing and friction clutches, which are operated by hand levers on the deck of the bridge.

Two wire ropes wind upon each drum from opposite directions; one entering on the lower side, and connecting with the gates which close one-half of the driveway and one sidewalk at one end of the draw; and the other entering upon the upper side of the same drum, and connecting with the corresponding gates at the diagonally opposite corner.

The two drums although on the same shaft are entirely independent of each other, and are set in motion by cone frictions operated by separate hand levers on the deck of the bridge.

The power is transmitted from the drums to the gates by $\frac{5}{8}$-inch iron rods and $\frac{1}{2}$-inch wire ropes carried on guide pulleys beneath the flooring.

The connections between the draw and fixed spans are automatic, so that when the gates have been closed all connections with the shore spans are released as the draw moves off.

The draw can be turned in either direction, or reversed, end for end, without interfering with the connections, and as the draw returns to place, the connections are again established.

At each of the four corners of the draw and in line with the railing is placed a frame, constructed of angle and tee iron, and supporting two 1½-inch vertical steel rods, upon which works a tongue slide. Upon the fixed spans and directly opposite, are similar frames each having two vertical rods, upon which works a grooved slide, which engages with the tongue slide on the draw. Neither the tongue nor the grooved slide can be moved vertically without carrying the other with it; but the two are entirely independent of each other when moved horizontally. The tongue slides are connected by rods and wire ropes with the drums at the center, and the grooved slides are connected with the grooved pulleys on the gate posts by wire ropes. On the ends of the top and bottom rail of each driveway gate is a projecting latch, which, as the end of the gate comes near to the wooden post at the center, engages with counterbalanced catches, thus fastening the gate securely. The sidewalk gates are held in position by the gear connection with the driveway gates. The gates are all unlatched at the same time by an independent lever at the center of the draw; the connection between the draw and fixed spans being made by a rod on the draw pushing against a plate on the fixed span.

The gates are operated as follows :

When the signal to open the draw is heard, the engine is started and the hand lever of the main friction clutch which connects the engine with the gate machinery is thrown over. The signal—three strokes of the bell—is given by the superintendent for all passing over the bridge to stop.

The No. 1 lever is thrown over, and the drum set in motion, which closes the pair of gates at the diagonally opposite corners, on the sides of the bridge by which teams approach the draw. The wire ropes wind on the drum thus set in motion, from opposite directions, raising the tongue slides and carrying with them the grooved slides on the fixed spans. Motion is thus communicated by the grooved slides to the wire ropes which pass around the pulleys on the driveway gate posts, and the gates are turned through an angle of 90 degrees and latched to the center posts. Just as the gates latch, the hand lever at the center is thrown back, which disconnects the drum from the engine. The ex-

treme backward throw of the lever operates a brake on the drum, which holds it firmly, and keeps the tongue slide exactly in the position where it stops. After the teams have all left the draw, the second pair of gates is closed in the same manner by the No. 2 lever. The main friction clutch lever is then thrown back and the draw is ready to be opened.

It will be observed that the only delay to the public from operating the gates, is the time which it takes to close the second pair of gates, which does not exceed about eight seconds. In opening the gates there is practically no delay to the public in waiting. As soon as the draw comes to rest the gates are all unlatched together and opened by the counter weights, the movement of the gates being under control of the superintendent at the center by means of the brakes on the drums. The counter weights are adjustable, varying from about 100 pounds in still weather, to 125 pounds or more in windy weather, for each of the four driveway gates.

In the erection of the gates and operating machinery, the work was so conducted, that, although requiring considerably more time, the bridge was not closed to travel.

The general arrangement of the gates, and the method of operating, especially the automatic connection between the draw and fixed spans, are believed to be entirely new in design.

The gates were erected in the fall of 1884 and were put into regular operation January 17th, 1885, and have since been in constant use up to the present time, a period of more than four years, giving entire satisfaction to the traveling public, and fulfilling all the requirements of safety, convenience and economy.

During the period of four years in which the gates have been in operation no repairs of importance have been made, except to renew the wire ropes as they have worn out; and no change in the machinery has been made, except to substitute for the two grooved drums at the center new ones with deeper grooves to prevent the wire ropes from getting out of place, and stranding on the edges of the grooves. The new drums were also lagged with hard wood on the surface against which the brake pressed, to avoid the slipping of the brakes when the frost was coming out of the iron, which had given some trouble under certain conditions of the weather in the winter.

This change in the drums has entirely remedied the trouble from the two sources mentioned above.

The gates and operating machinery were designed, and their erection superintended by the writer, acting under the general instruction of the City Engineer, Samuel M. Gray, M. Am. Soc. C. E. Valuable assistance was rendered by H. N. Francis, M. Am. Soc. C. E., in the preparation of working drawings and the erection of the gates.

POINT ST. BRI

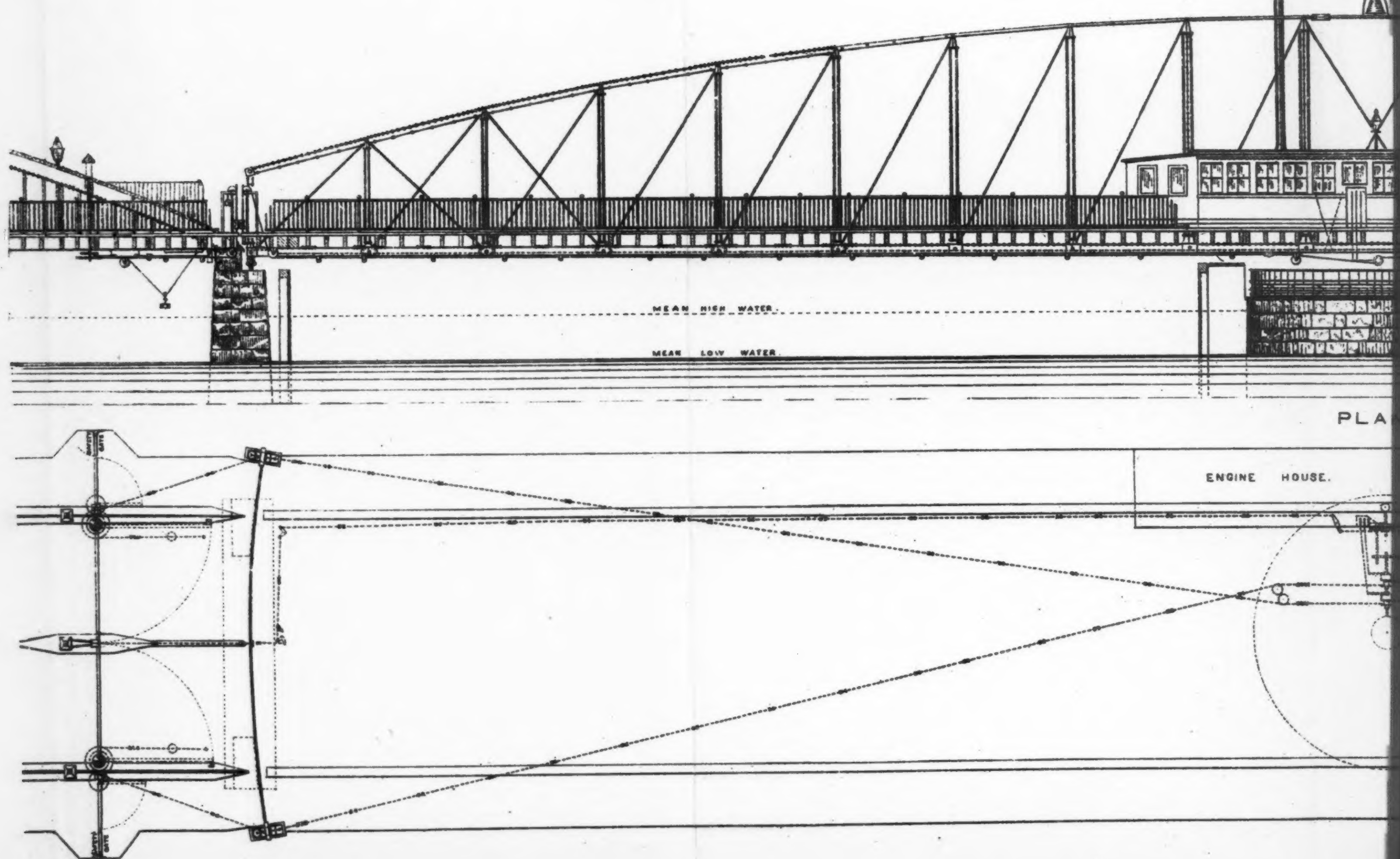
PLAN AND E

SHOWING GENERAL ARRANGEMENT

PROVIDENCE

SCALE OF

SIDE ELE



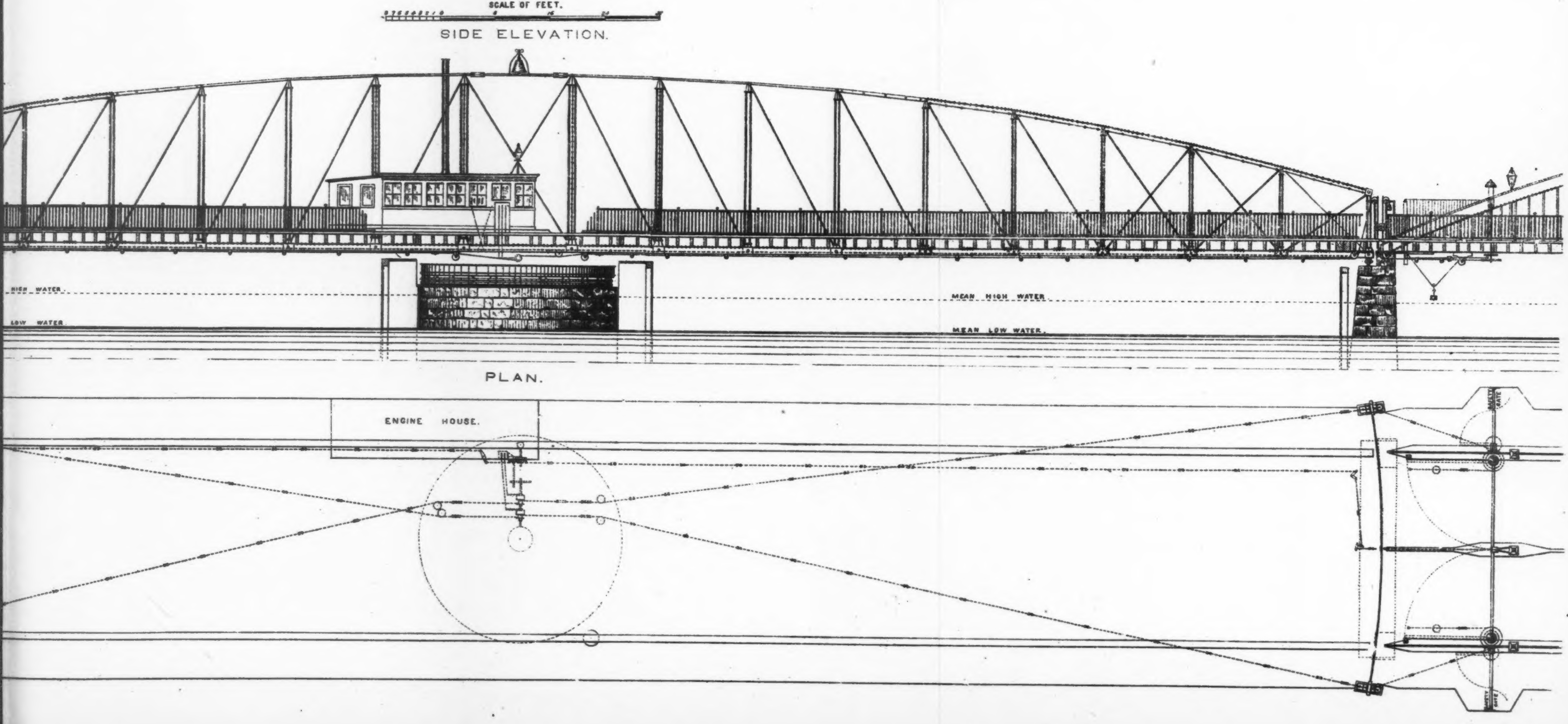
POINT ST. BRIDGE GATES.

PLAN AND ELEVATION

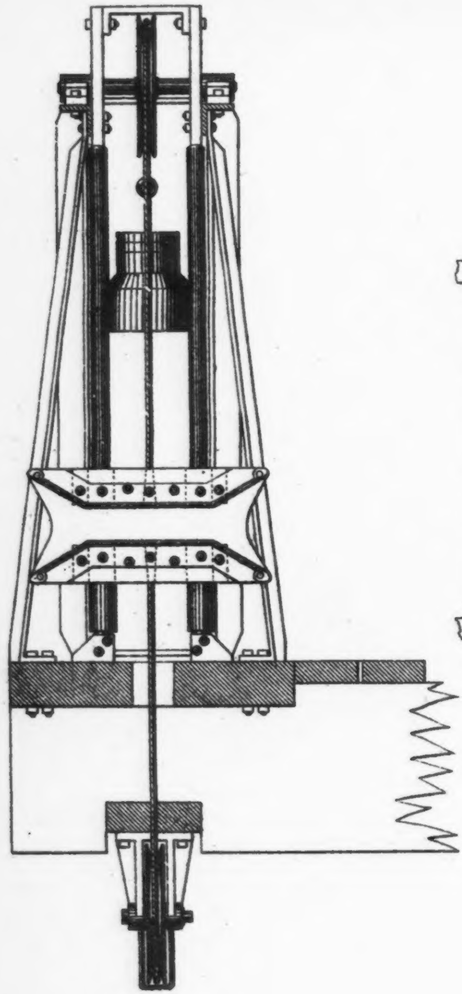
SHOWING GENERAL ARRANGEMENT AND CONNECTIONS OF GATES.

PROVIDENCE R. I. 1884.

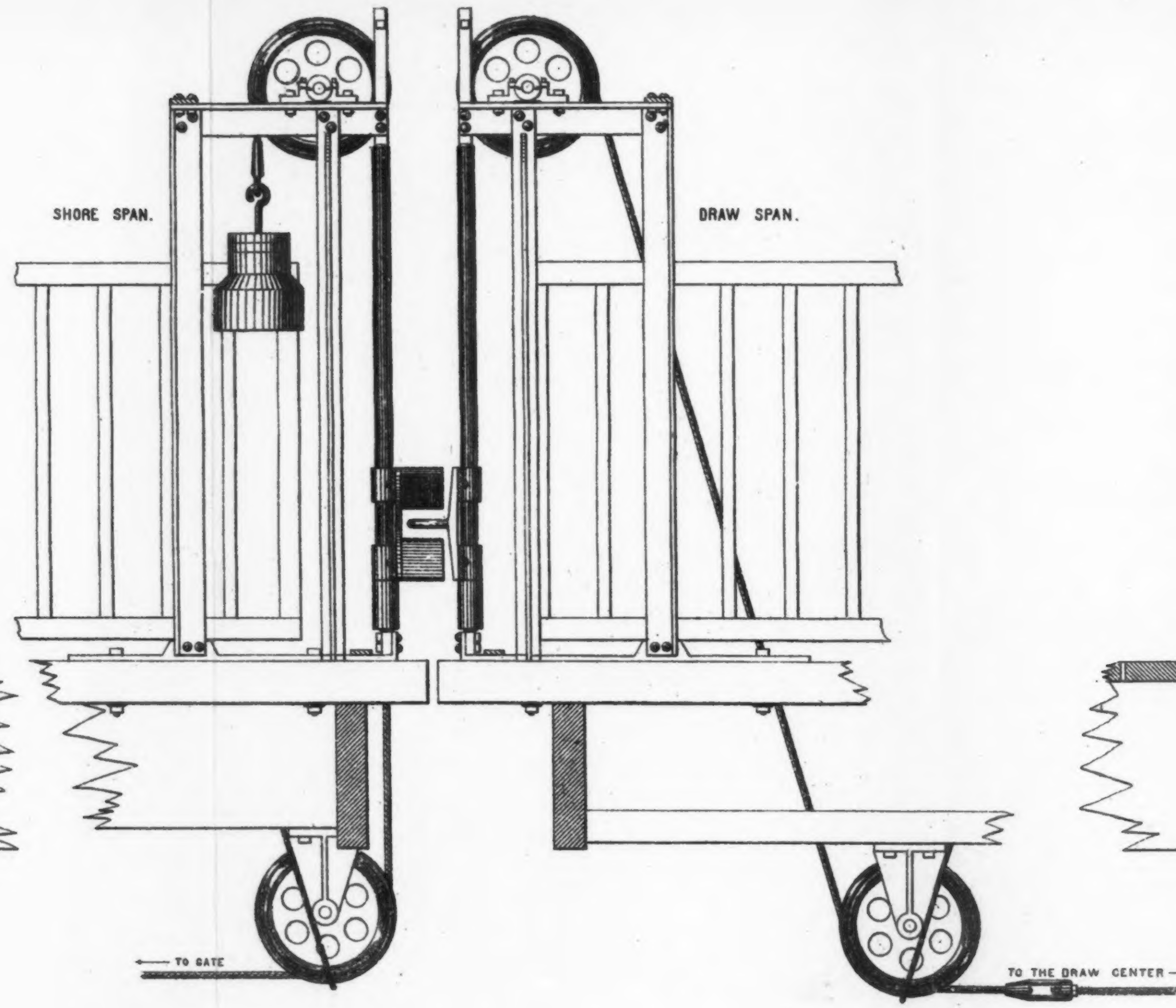
PLATE. III.
TRANS. AM. SOC. CIV. ENG'RS.
VOL. XX Nº 405
BULLOCK ON
BRIDGE GUARD GATES.



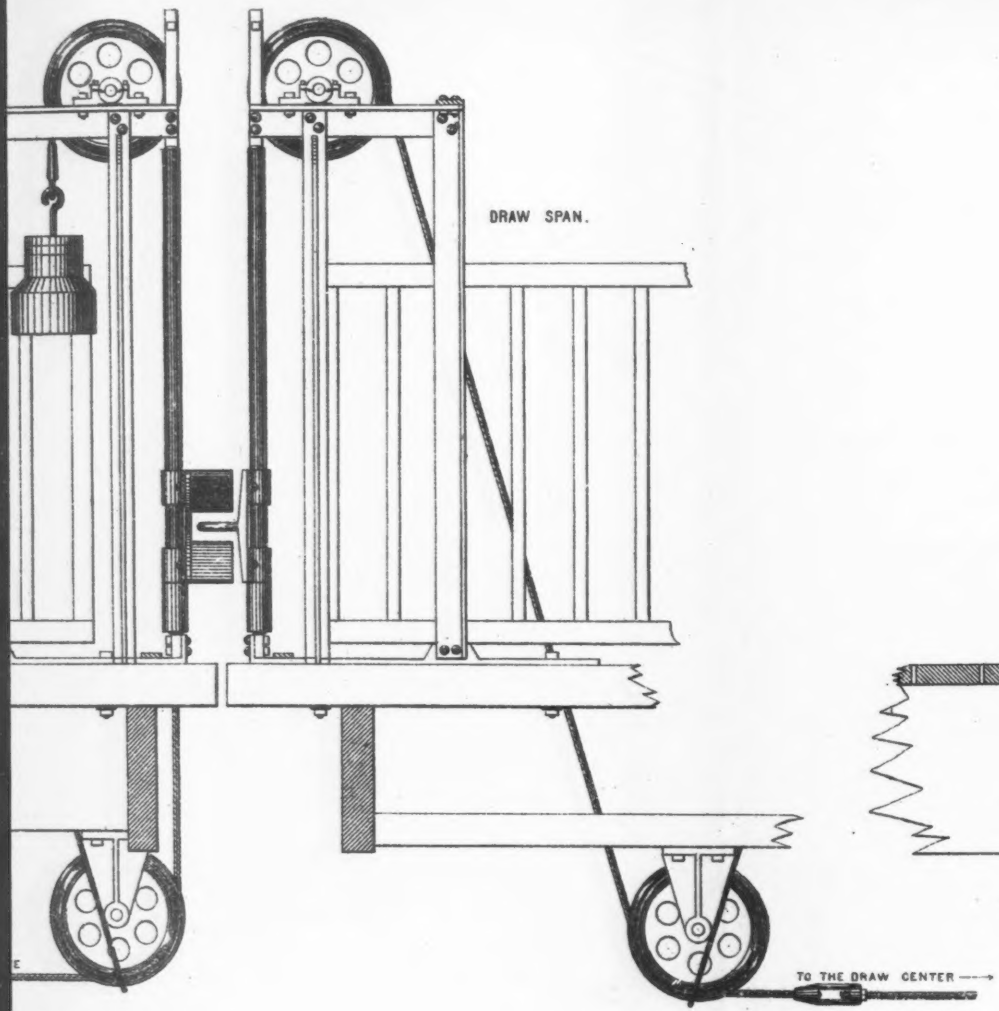
ELEVATION OF
GROOVE SLIDE AND FRAME.



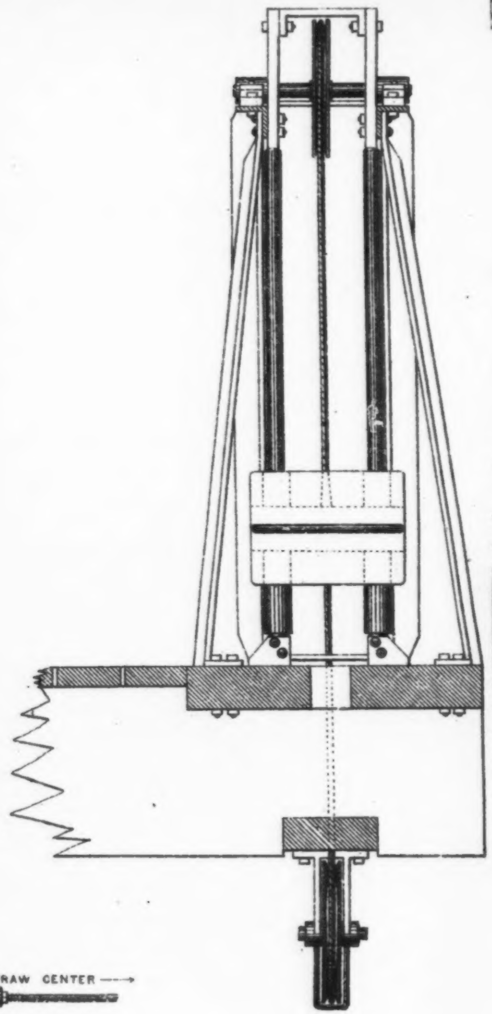
SIDE ELEVATION OF AUTOMATIC CONNECTION
BETWEEN THE DRAW AND SHORE SPANS.

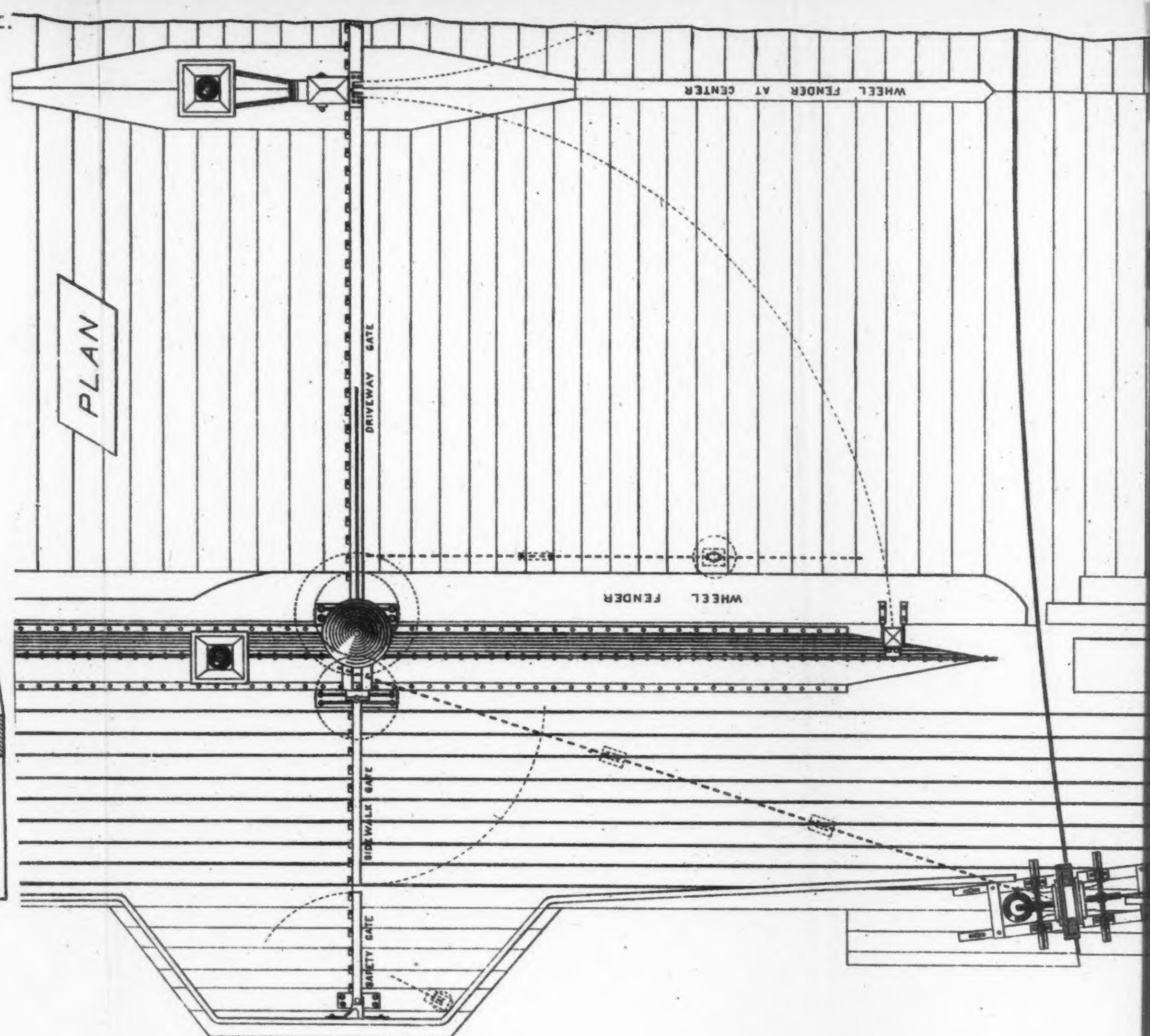


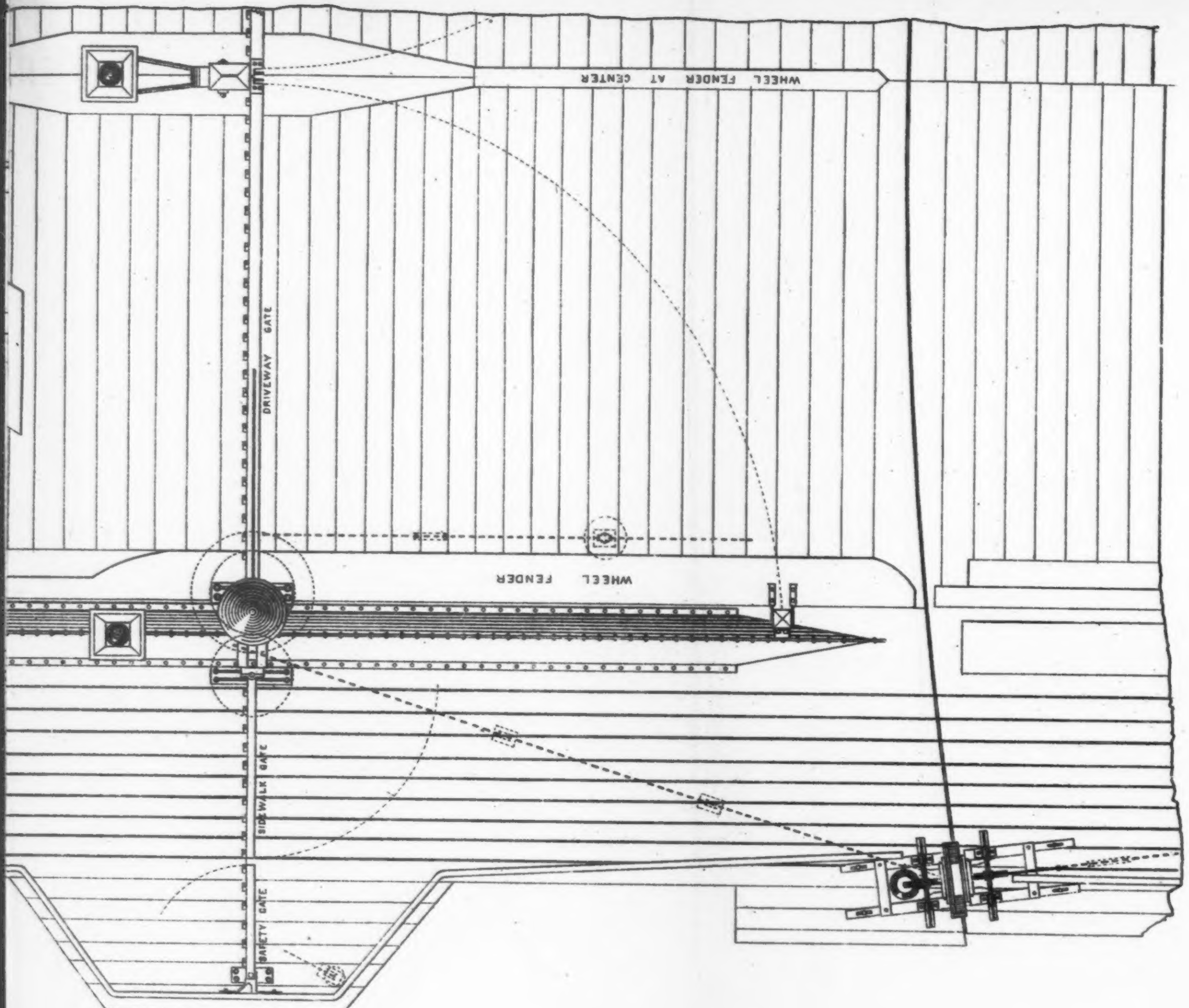
IDE ELEVATION OF AUTOMATIC CONNECTION
ETWEEN THE DRAW AND SHORE SPANS.



ELEVATION OF
TONGUE SLIDE AND FRAME.







POINT ST. BRIDGE GATES.

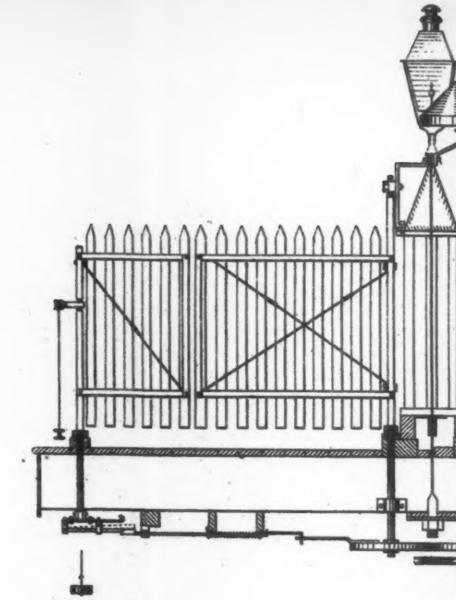
PLAN AND ELEVATION,

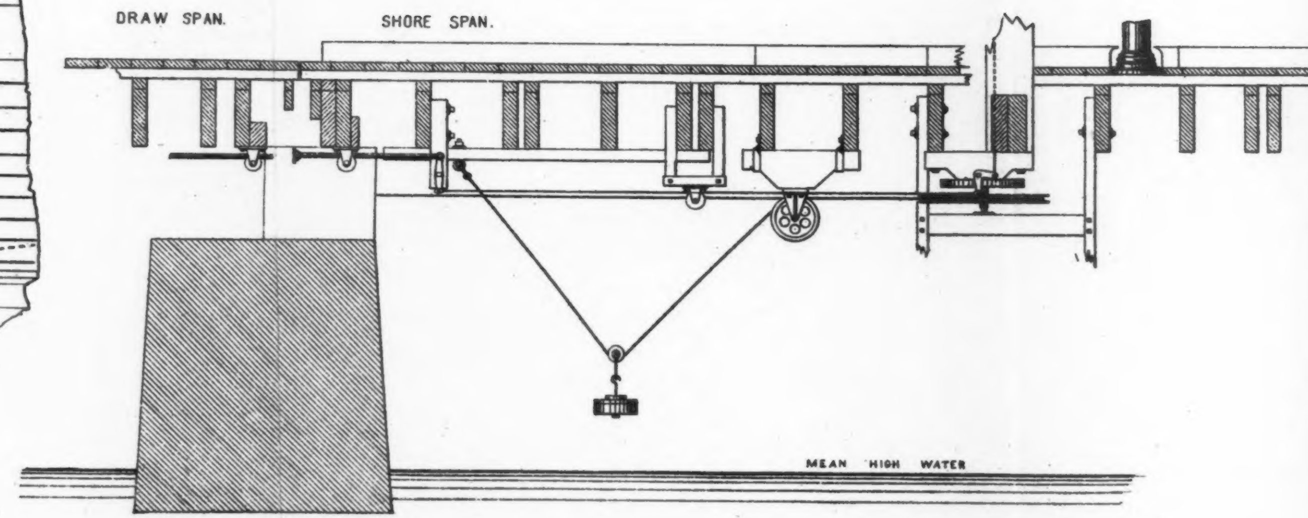
WITH DETAILS OF AUTOMATIC CONNECTIONS.

PROVIDENCE R. I. 1884.

SCALE OF FEET FOR PLAN AND ELEVATION.

SCALE OF FEET FOR SLIDE CONNECTIONS.





T ST. BRIDGE GATES.

PLAN AND ELEVATION,

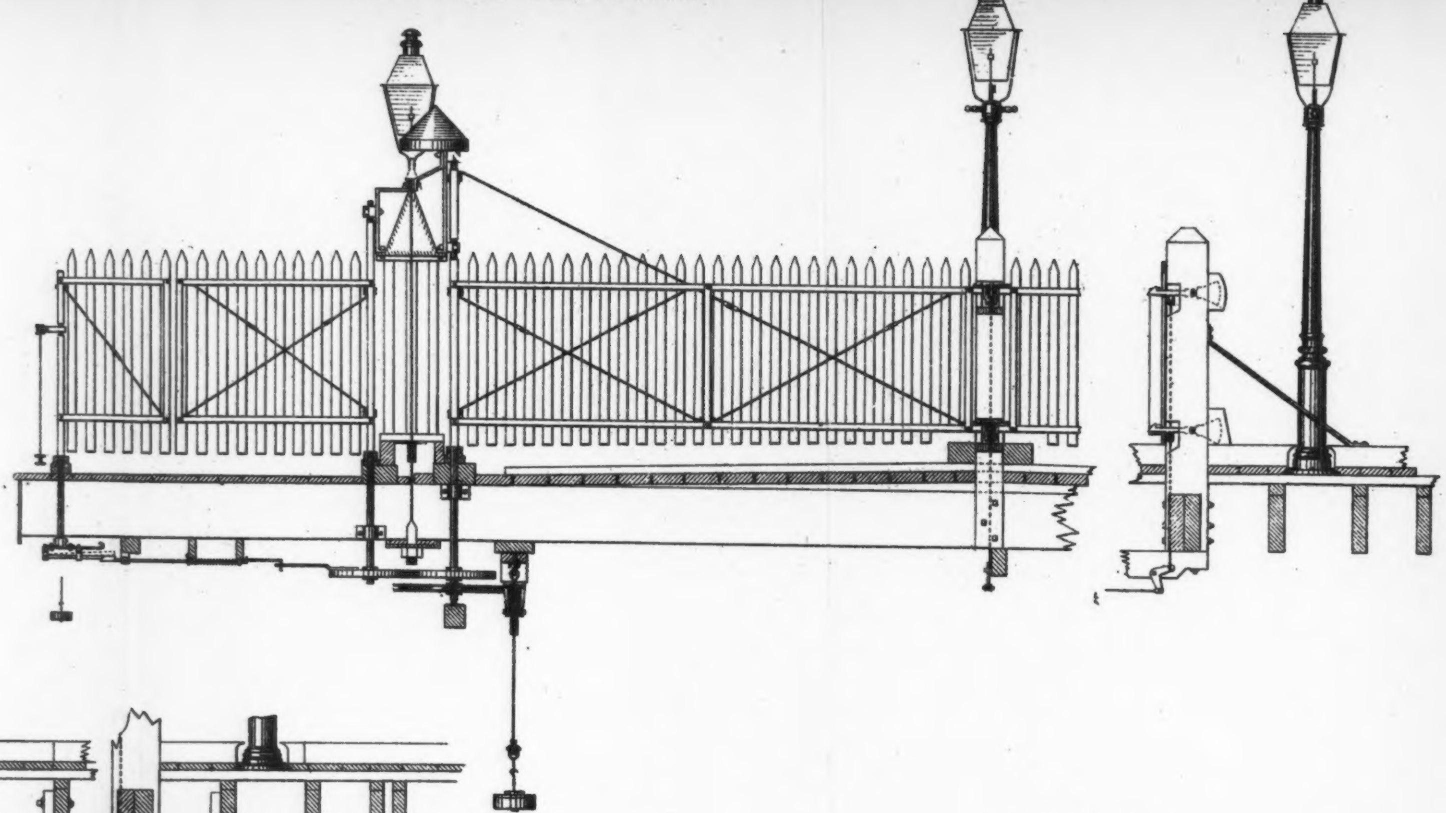
ETAILS OF AUTOMATIC CONNECTIONS.

PROVIDENCE R. I. 1884.

SCALE OF FEET FOR PLAN AND ELEVATION.

SCALE OF FEET FOR SLIDE CONNECTIONS.

SECTIONAL ELEVATION



SHORE SPAN.

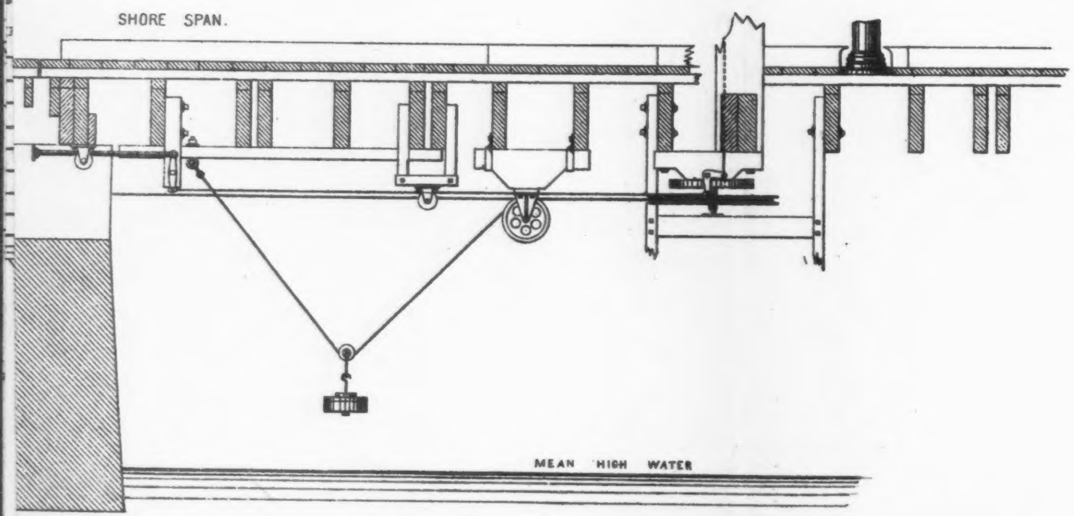
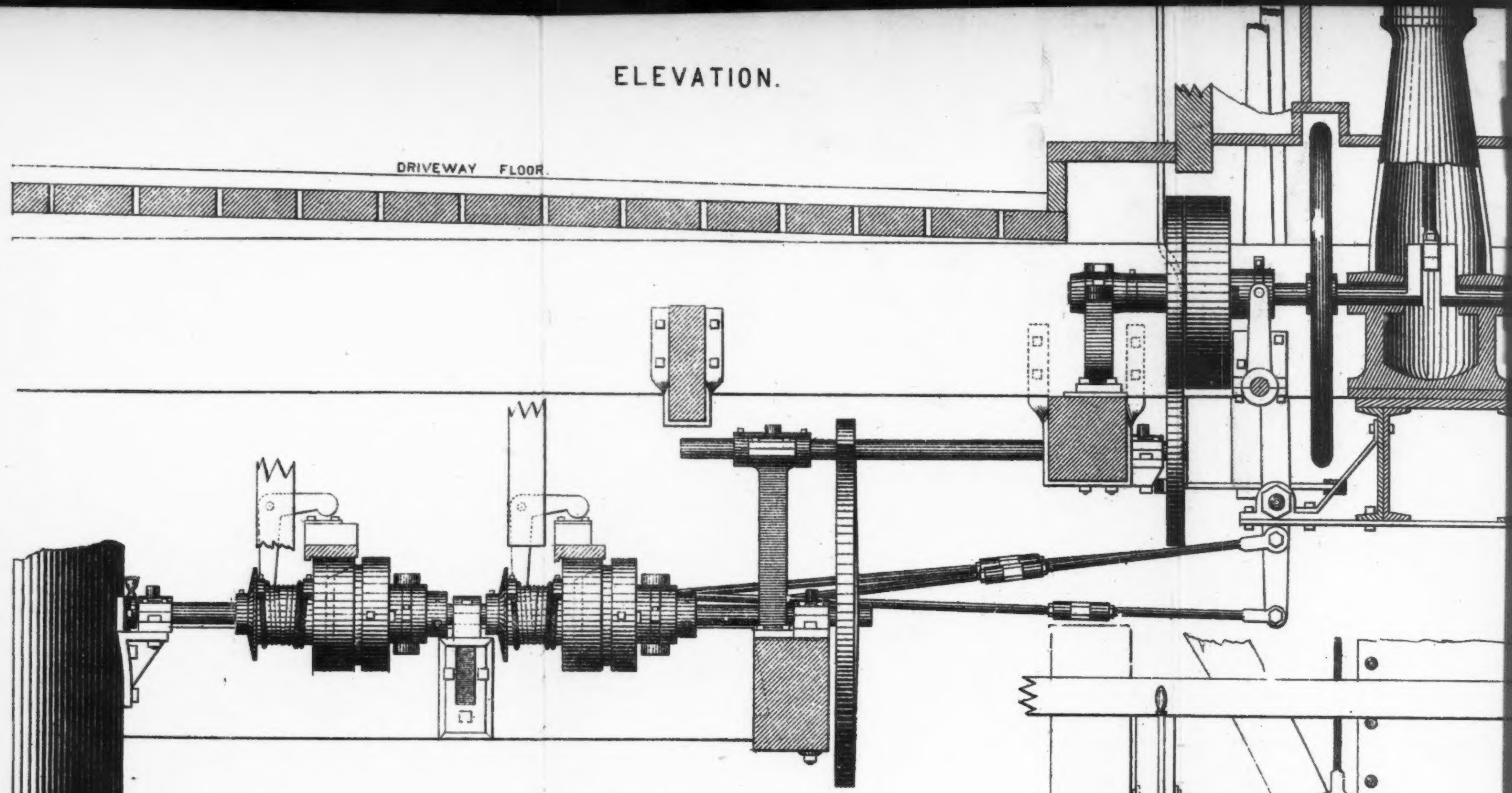


PLATE IV.
TRANS. AM. SOC. CIV. ENG'RS.
VOL. XX. Nº 405
BULLOCK ON
BRIDGE GUARD GATES.

ELEVATION.



PLAN.

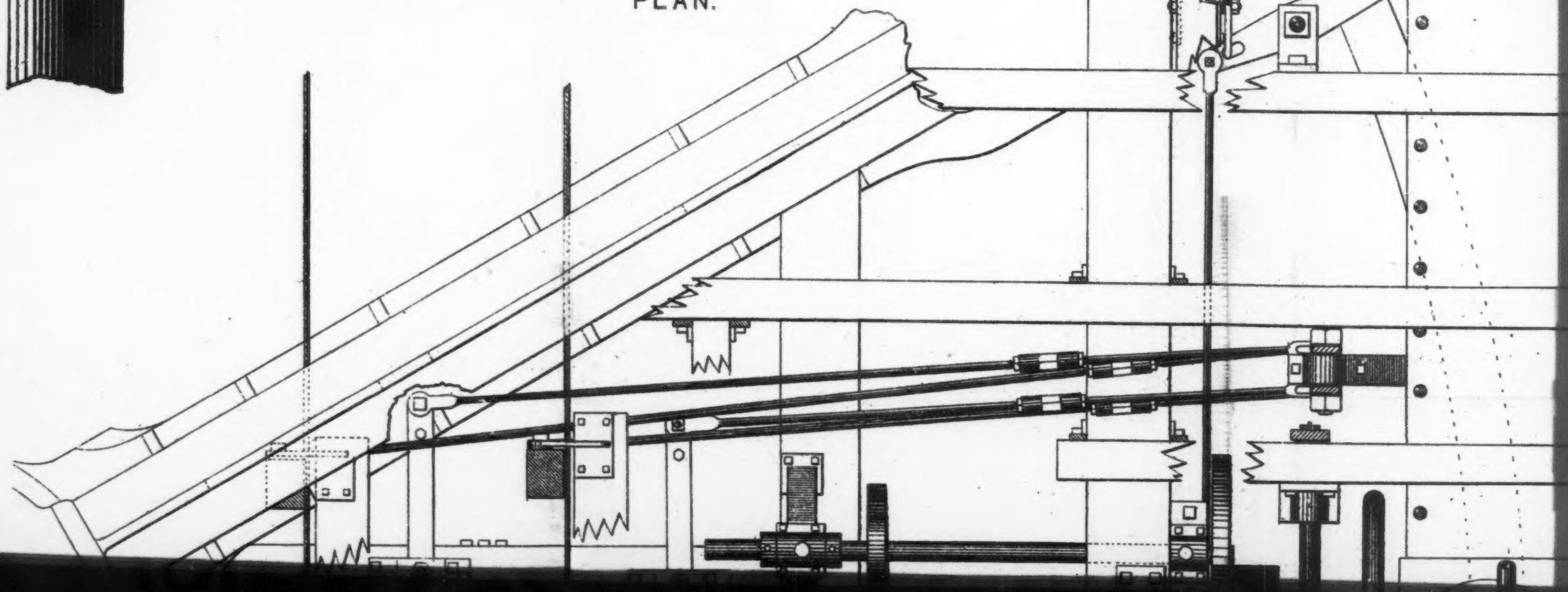
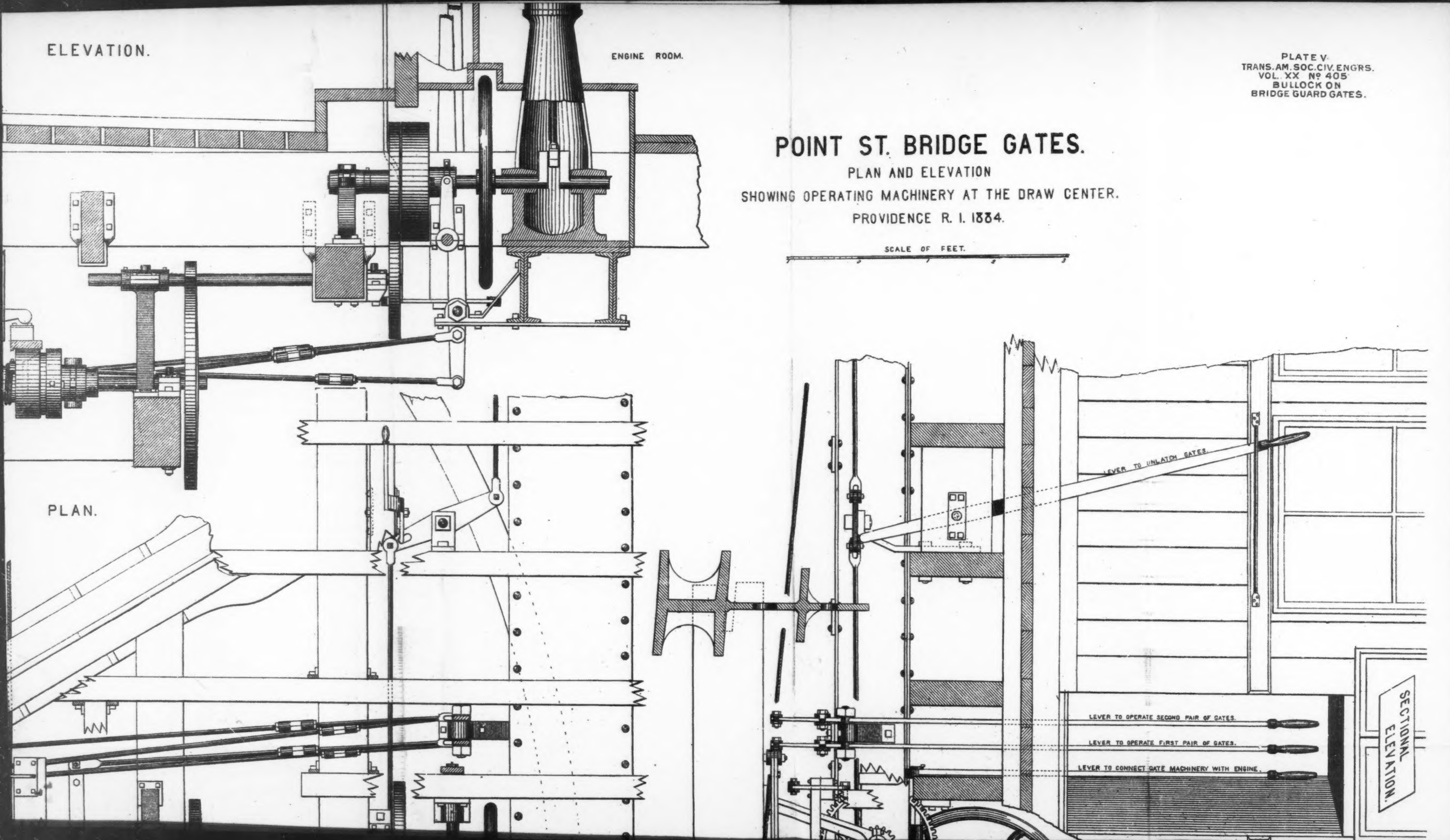
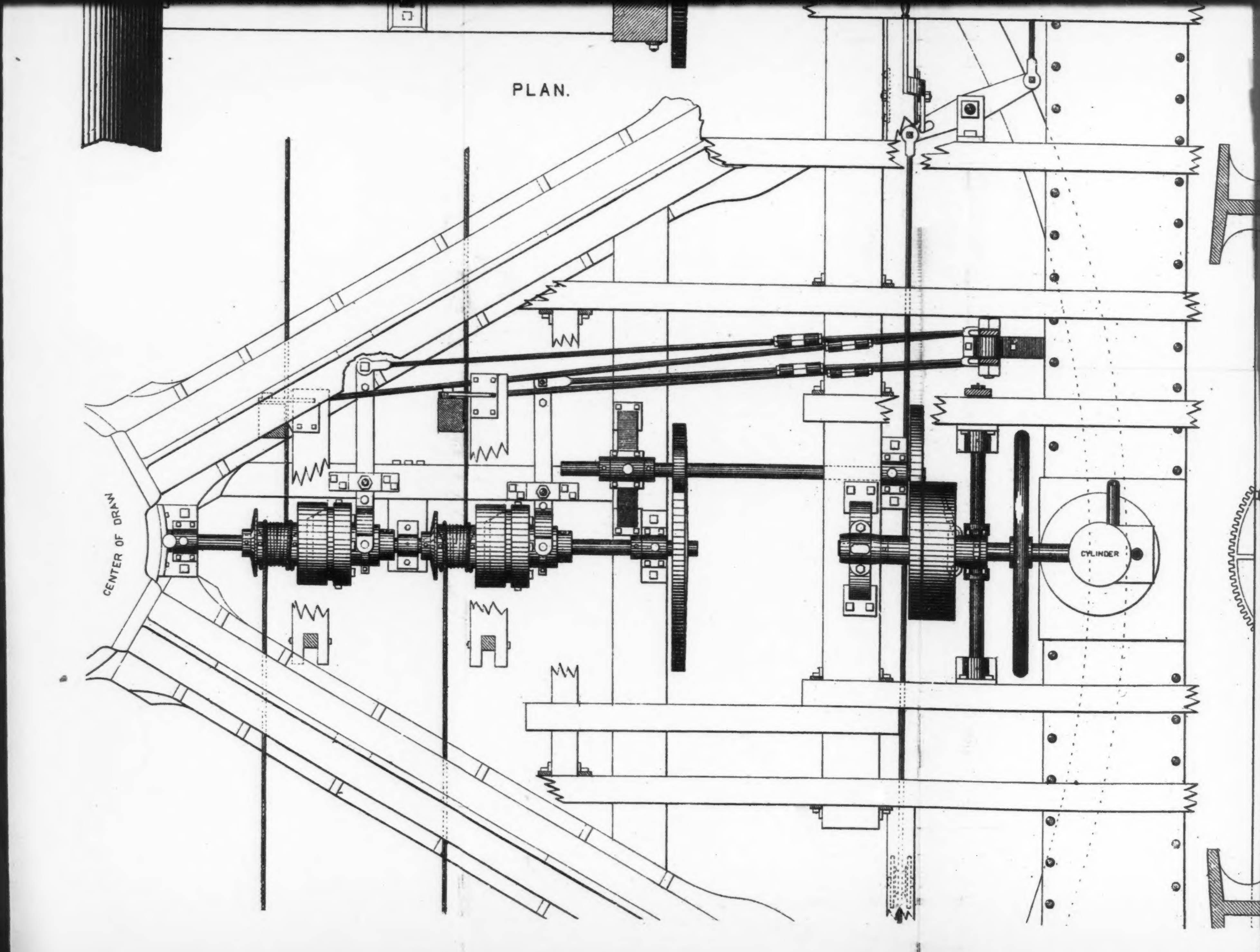


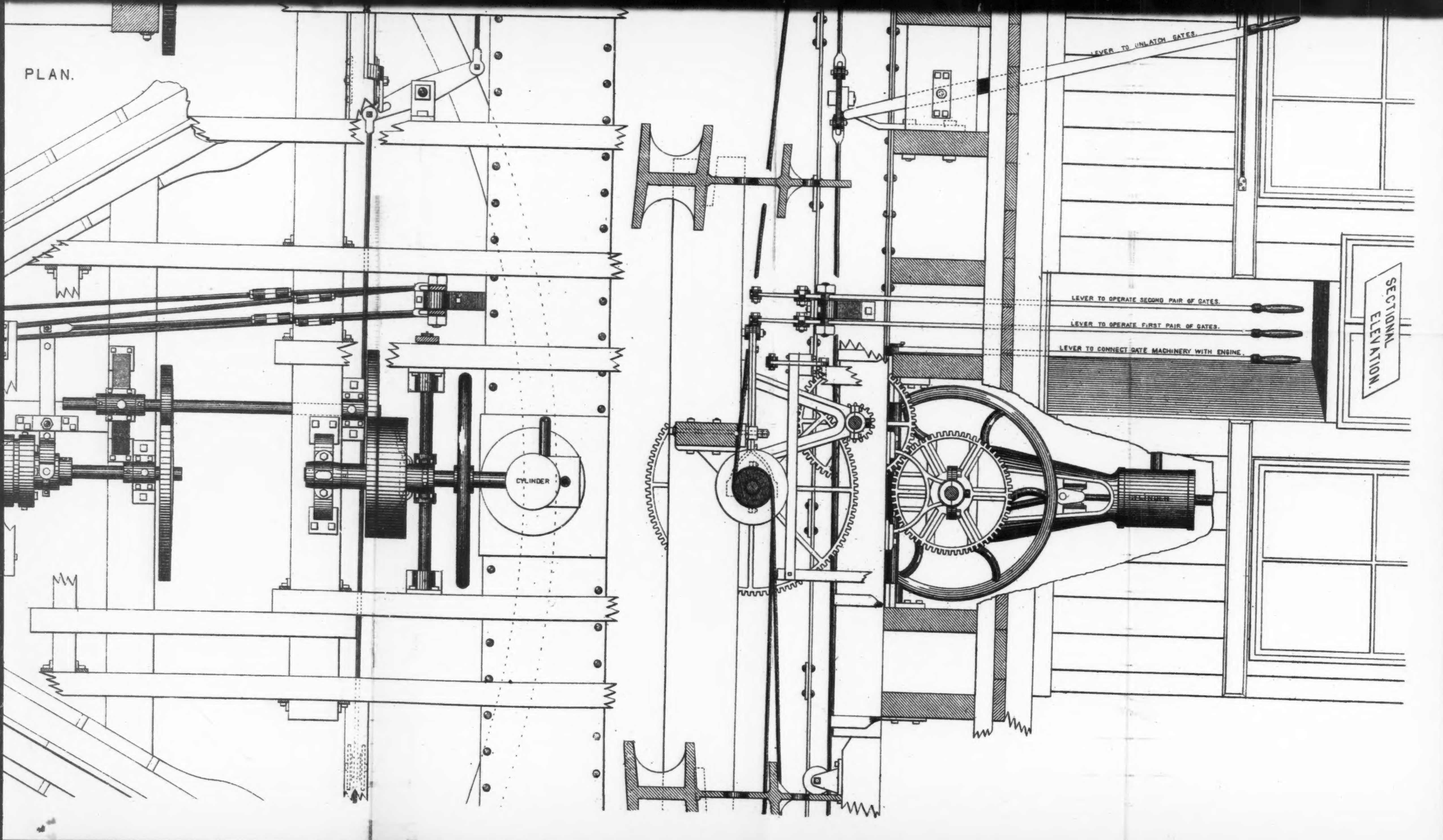
PLATE V.
TRANS. AM. SOC. CIV. ENGRS.
VOL. XX Nº 405
BULLOCK ON
BRIDGE GUARD GATES.

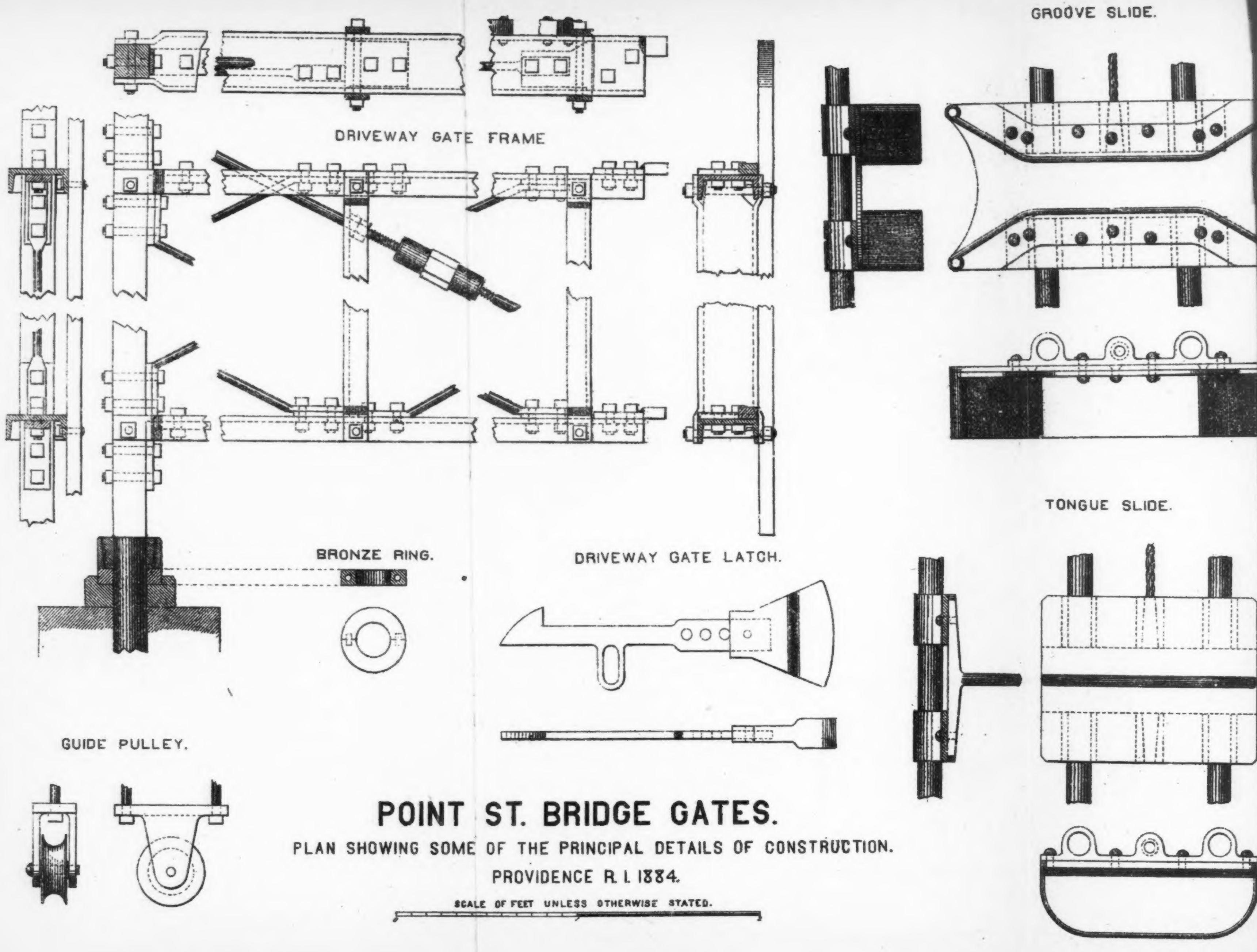
POINT ST. BRIDGE GATES.

PLAN AND ELEVATION
SHOWING OPERATING MACHINERY AT THE DRAW CENTER.
PROVIDENCE R. I. 1884.




PLAN.
CENTER OF DRAW
CYLINDER


PLAN.
CYLINDER
LEVER TO UNLATCH GATES.
LEVER TO OPERATE SECOND PAIR OF GATES.
LEVER TO OPERATE FIRST PAIR OF GATES.
LEVER TO CONNECT GATE MACHINERY WITH ENGINE.
SECTIONAL ELEVATION.



POINT ST. BRIDGE GATES.

PLAN SHOWING SOME OF THE PRINCIPAL DETAILS OF CONSTRUCTION.

PROVIDENCE R. I. 1884.

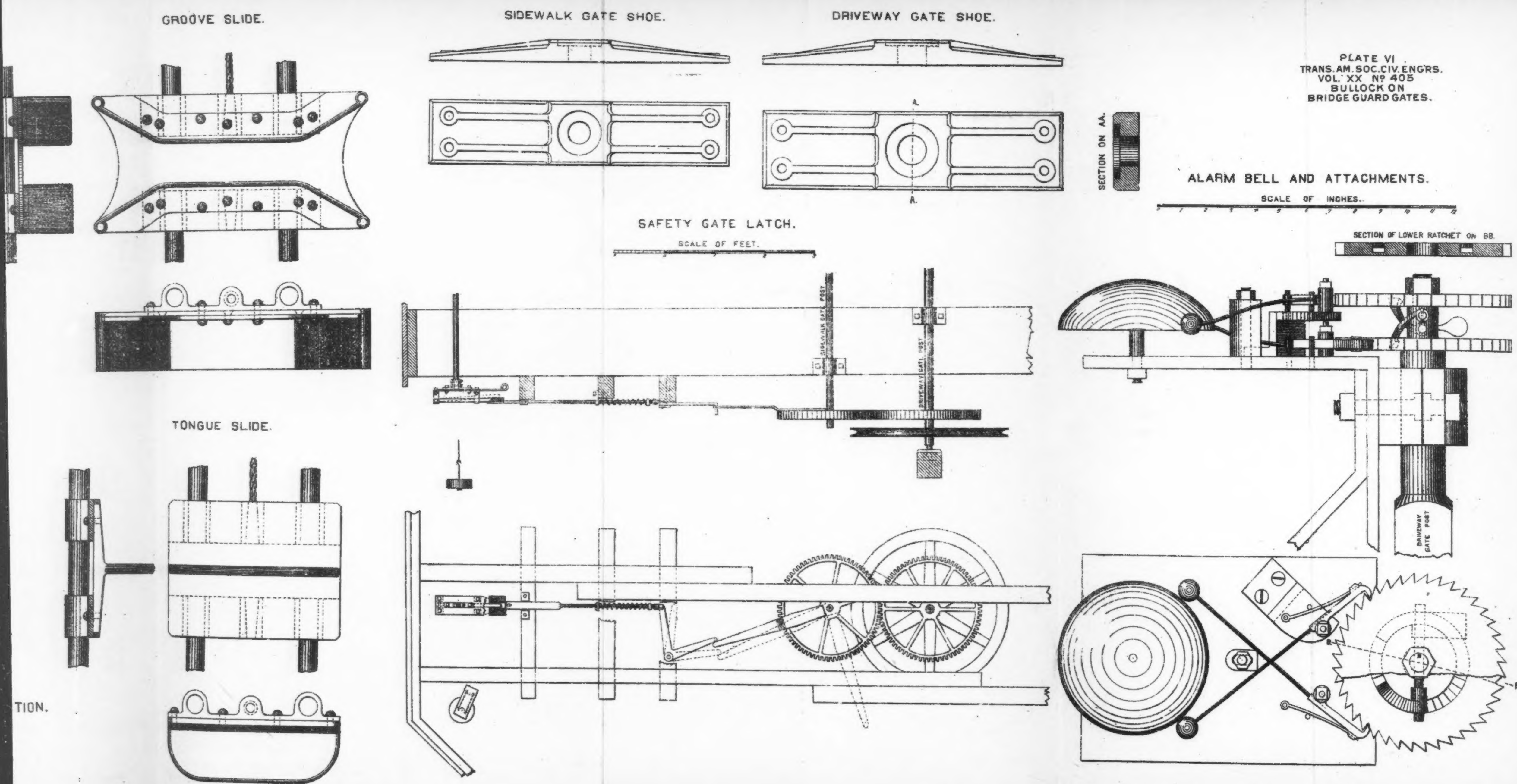


PLATE VI.
TRANS. AM. SOC. CIV. ENG'RS.
VOL. XX No 405
BULLOCK ON
BRIDGE GUARD GATES.
GROOVE SLIDE.
SIDEWALK GATE SHOE.
DRIVEWAY GATE SHOE.
A.
A.
SECTION ON AA.
ALARM BELL AND ATTACHMENTS.
SCALE OF INCHES.
SECTION OF LOWER RATCHET ON BB.
SAFETY GATE LATCH.
SCALE OF FEET.
SIDEWALK GATE POST
DRIVEWAY GATE POST
TONGUE SLIDE.
DRIVEWAY GATE POST
B
B
TION.